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Mechanical Characterization of Reinforced Aluminum Alloy Zircal

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Abstract: *The Al–Zn–Mg–Cu Aluminum alloy known as Al 7075 is a very useful material because of its mechanical properties i.e. low density, high strength, moderate ductility and toughness. Due to these properties, this alloy is mainly used for highly stressed structural parts. This material has a wide range of application such as aircraft fittings, gears and shafts, fuse parts, meter shafts and gear, missile parts, regulating valve parts, worm gears, keys and various other parts of commercial aircrafts and aerospace vehicles. The main objective of our work is to improve the mechanicals properties such as hardness, tensile strength, compressive strength of Aluminum based composite, and its relation with processing of the Alumina particulate (Al_2O_3) as reinforced in fly ash matrix. Aluminum 7075 alloy is chosen as matrix alloy, in which Aluminum is the base element. The work has been proposed for hardness test, compression test and tensile test. Mechanical properties as a tensile test, hardness test are conducted on Al 7075 reinforced with fly ash. These reinforcements provide comparatively high strength and hardness.*

Keywords—Al 7075; mechanical properties; hardness test; tensile strength; compressive strength

1. Introduction

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal composites possess significantly improved properties including high specific strength, specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of fly ash particles in aluminum alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminum and thereby, reducing the cost of aluminum products. Now the days the particulate reinforced aluminum composites are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast aluminum matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys [1]. In the present work, fly-ash which mainly consists of refractory oxides like silica, alumina, and iron oxides is used as reinforcing phase. Composite was produced with 10gm to 40gm fly ash as reinforcing phase. Commercially pure aluminum was also melted and casted. Then particle size and chemical composition analysis for fly-ash was done. Mechanical, physical and grain properties of the composite were evaluated and compared with the commercially pure aluminum. Mechanical properties of composites are affected by the size, shape and volume fraction of the reinforcement, composite material and reaction at the interface.

2. AL 7075 ALLOY CHARACTERISTICS

2.1 Al 7075 microstructure

Al 7075 alloy is perfect for applications where high strength is essential and good corrosion resistance is less important. It is known to have a high strength to weight ratio and certain tempers offer decent resistance to stress-corrosion cracking. 7075 is able to match most steel alloys in terms of strength [2]

Fig.1. *Microstructure of base alloy 7075*

2.2 Composition of Al 7075

Table 1: Composition of Al 7075

Material	***Weight %***
Copper	1.53
Chromium	0.20
Magnesium	2.50
Zinc	5.45
Iron	0.20
Manganese	0.25
Silicon	0.30
Titanium	0.16
Aluminum	Remaining

2.3 Properties of Al 7075

Table 2: Properties of Al 7075

Mechanical properties	***Value***
Hardness - Brinell	94.95
Tensile yield strength	198.9MPa
Elongation at break	5.40%
Modulus of elasticity	71.7GPa
Poisson’s ratio	0.33
Shear modulus	26.9GPa
Shear strength	331MPa

2.4 Composite material

The composite material can be defined as the system of material consisting of a mixture of combination of two or more micro constituents insoluble in each other and differing in form and or in material composition .These materials can be prepared by putting two or more dissimilar material in such way that they function mechanically as a single unit. The properties of such materials differ from those of their constituents. These materials may have a hard phase embedded in a soft phase or vice versa. Normally in the composite material have a hard phase in the soft ductile matrix where the hard phase act as a reinforcing agent increase the strength and modulus, and soft phase act as matrix material [3]. The requirement for satisfying the above mentioned condition is:

a. The composite material has to be man-made

b. The composite material must be a combination of at least two chemically distinct materials with an interface separating the components.

c. The properties of composite should be three dimensionally combined.

2.5 Classification of composite

On the basis of Matrix composite can be classified in the following groups:

- Polymer-matrix composites (PMC): The most common matrix materials for composites are polymeric. Polyester and vinyl esters are the most widely used and least expensive polymer resins. These matrix materials are basically used for fiber glass reinforced composites. For mutations of a large number resin provide a wide range of properties for these materials .The epoxies are more expensive and in addition to wide range of ranging commercials applications ,also find use in PMCs for aerospace applications. The main disadvantages of PMCs are their low maximum working temperature high coefficients of thermal expansion and hence dimensional instability and sensitivity to radiation and moisture. The strength and stuffiness are low compared with metals and ceramics.

- Metal-matrix composites (MMC): The matrix in these composites is a ductile metals .These composites can be used at higher service temperature than their base metal counterparts. These reinforcements in these materials may improve specific stuffiness specific strength, abrasion resistance, creep resistance and dimensional stability. The MMCs is light in weight and resist wear and thermal distortion, so it mainly used in automobile industry. Metal matrix composites are much more expensive those PMCs and, therefore, their use is somewhat restricted. [4, 5]

- Ceramic-matrix composites (CMC): One of the main objectives in producing CMCs is to increase the toughness. Ceramics materials are inherent resistant to oxidation and deterioration at elevated temperatures; were it not for their disposition to brittle fracture, some of these

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materials would be idea candidates for use in higher temperature and serve-stress applications, specifically for components in automobile an air craft gas turbine engines .The developments of CMCs has lagged behind mostly for remain reason, most processing route involve higher temperature and only employed with high temperature reinforcements.

On the basics of reinforcement can be classified into three types:

- Particle reinforced composites Particulate reinforcements have dimensions that are approximately equal in all directions .The shape of the reinforcing particles may be spherical, cubic, platelet or any regular or irregular geometry. These composite can classified under two sub groups : **(i)** Large particle composites **(ii)** Dispersion strengthened composites

- Fiber reinforced composites A fibrous reinforcement is characterized by its length being much greater than its cross- sectional dimension .However the ratio of length to the cross sectional dimension know as the aspect ratio, can vary considerably .In single layer composite long fibers with high aspect ratios give that are called continuous fiber reinforced composites whereas discontinuous fiber reinforced composites are fabricated using short fibers of low aspect ratio .The orientation of the discontinuous fibers may be random or preferred .

2.6 Aluminum fly ash particulate reinforced composite

[6] Has worked on the Effect of reinforcement of fly ash on sliding wear, slurry erosive wear and corrosive behavior of aluminum matrix composite. Al (12 wt% Si) as matrix material and up to 15 wt% of fly ash particulate composite was fabricated using the stir casting rote and came forward into following conclusions Fly ash improves abrasive wear resistance (20-30%) of Al. and reduces the coefficient of Friction. Increase in normal load and sliding velocity increases magnitude of wear and frictional force. Different wear mechanisms were studied under varying different parameter such as normal load, % of fly ash content and sliding velocity. Four different mechanisms are found that are abrasion, oxidation, delaminating, thermal softening and adhesion. Corrosion resistance of reinforced composite has decreased with increase in fly ash content. [7] Has synthesized A356 Al fly ash particle composites .They studied mechanical properties and dry sliding wear and come into brief idea that Fly ash with narrow size range (53–106μm) show better properties compared with the wider size range (0.5–400μm) particles. The damping capacity of composite increases with the increase in volume fraction of fly ash. Fracture surface of composites show mixed mode (ductile and brittle) fracture. The 6%of fly ash particles into A356 Al alloy shows low wear rates at low loads (10 and 20 N) while12% of fly ash reinforced composites show lower wear rates compared to the unreinforced alloy in the load range 20–80 N.

The types of wear dominant in unreinforced alloy are adhesive wear, whereas abrasive wear is predominant in composites. At higher load, subsurface delaminating is the main mechanism in both the alloy as well in composites. [4] while studding the changes of chemical reaction between the Al and the fly ash during synthesis or reheating of fly ash found out that. The chemical reactions do occur between the fly ash an Al melts. The $SiO_2$and Fe_2O_3 present in the fly ash is reduced to Si and Fe .The melt oxidized to Al_2O_3.

2.7 Fly ash

Fly ash is one of the residues generated in the combustion of coal. It is an industrial byproduct recovered from the flue gas of coal burning electric power plants. Depending upon the source and makeup of the coal being burned, the components of the fly ash produced vary considerably, but all fly ash includes substantial amounts of silica (silicon dioxide, SiO_2) (both amorphous and crystalline) and lime (calcium oxide, CaO). In general, fly ash consists of SiO_2, Al_2O_3, and Fe_2O_3 as major constituents and oxides of Mg, Ca, Na, K etc. as minor constituent [8]. Fly ash particles are mostly spherical in shape and range from less than 1μm to 100μm with a specific surface area, typically between 250 and 600m^2/kg. The specific gravity of fly ash vary in the range of 0.6-2.8gm/cc. Coal fly ash has many uses including as a cement additive, in masonry blocks, as a concrete admixture, as a material in lightweight alloys, as a concrete aggregate, in flow able fill materials, in roadway/runway construction, in structural fill materials, as roofing granules, and in grouting [9]. The largest application of fly ash is in the cement and concrete industry, though, creative new uses for fly ash are being actively sought like use of fly ash for the fabrication of MMCs.

Fig.2. *Fly ash particles [8]*

The preference to use fly ash as a filler or reinforcement in metal and polymer matrices is that fly ash is a byproduct of coal combustion, available in very large quantities at very low costs since much of this is currently land filled. Currently, the use of manufactured glass micro spheres has limited applications due mainly to their high cost of production. Therefore, the material costs of composites can be reduced significantly by incorporating fly ash into the matrices of polymers and metallic alloys. The high electrical

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resistivity, low thermal conductivity and low density of fly-ash may be helpful for making a light weight insulating composites. Fly ash as a filler in Al casting reduces cost, decreases density and increase hardness, stiffness, wear and abrasion resistance. It also improves the maintainability, damping capacity, coefficient of friction etc. which are needed in various industries like automotive etc. As the production of Al is reduced by the utilization of fly ash. This reduces the generation of green house gases as they are produced during the bauxite processing and alumina reduction [10.

3. EXPERIMENTAL PROCEDUES

3.1 Material studied

The Al 7075 alloy (matrix material), reinforcement Fly ash were used for fabrication of MMCs, Al 7075, Al 6061 and pure Al

3.2 Composite preparation

The aluminum fly ash metal matrix composite was prepared by stir casting route. For this we took pure aluminum and desired amount of fly ash particles. The fly ash particle was preheated to 300°C for three hour to remove moisture. Commercially pure aluminum was melted in a resistance furnace. The melt temperature was raised up to 720°C and then the melt was stirred. The melt temperature was maintained 700°C during addition of fly ash particles. The melt with reinforced particulates were poured into the preheated permanent metallic mold. The pouring temperature was maintained at 680°C.The melt was then allow to solidify the moulds. Magnesium and silicon were added to increase the wettability of fly ash particles [11].

4. RESULTS AND DISCUSSIONS

4.1 Hardness

The Brinell hardness test method as used to determine Brinell hardness is defined in ASTM E10 standard test method [10]. Most commonly it is used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method Brinell hardness is determined by forcing a hard steel or carbide sphere of a specified diameter under a specified load into the surface of a material and measuring the diameter of the indentation left after the test. The Brinell hardness number, or simply the Brinell number, is obtained by dividing the load used, in kilograms, by the actual surface area of the indentation, in square millimeters. The result is a pressure measurement, but the units are rarely stated. The BHN is calculated according to the following formula:

$$HBW = \frac{2F}{\pi D\left[D - \sqrt{(D^2 - d^2)}\right]}$$

Where:

HBW = the Brinell hardness

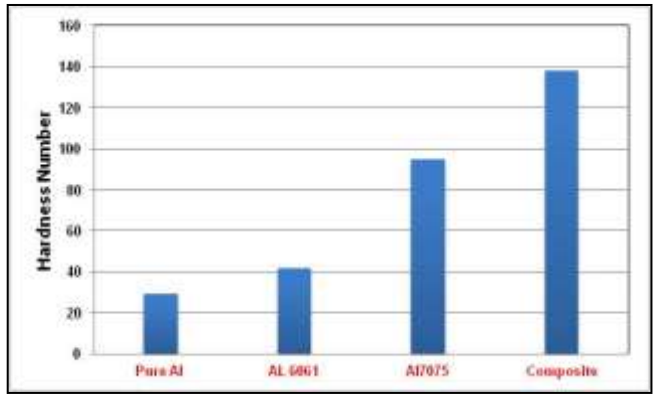
F = the imposed load in kg

D = the diameter of the spherical indenter in mm

d = diameter of the resulting indenter impression in mm

Hardness tests were carried out on samples by applying 40 grams of load for a period of 15 seconds. Fig.3 shows that the hardness increase with weight percentage of reinforcement in Al7075 matrix alloy and observed higher hardness in composite compare to matrix material

Fig.3. *Hardness test results*



4.2 Tensile test

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to uni-axial tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation & reduction in area. The tensile specimens of diameter 6 mm and gauge length 37 mm were machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the castings.

Fig.4. *UTS for different materials*

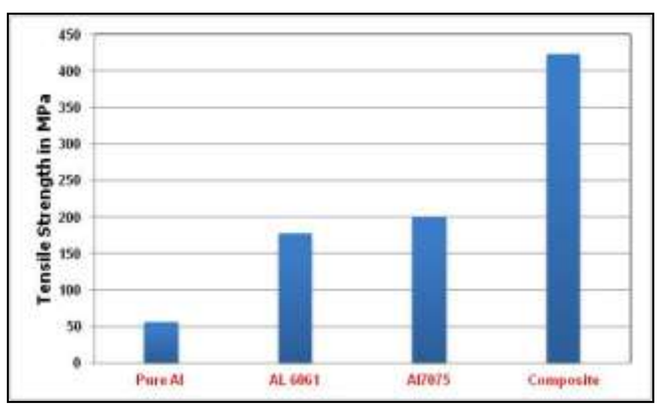


Fig.4 suggests shows that, the ultimate tensile strength is increases with increase in weight percentage of reinforcement in Al7075 matrix alloy and observed composite has superior ultimate tensile strength (UTS) by the addition of fly ach particles in matrix material. It is clears that composite has a higher strength compared to base alloy.

4.3 Compressive strength

The compression test specimens were machined to have cylindrical shape with 10 mm diameter and 10 mm height. Isothermal compression tests at constant strain rates and constant temperatures were conducted. The maximum compression equivalent strain of 0.2 was achieved in the test. Before beginning the test, the specimens were held in the die for some minutes to allow the material to reach steady state. The temperature was measured using thermocouples. Carbon powder was used as a lubricant to decrease the effect of friction and barreling. The deformation temperature and strain rate were automatically controlled by the machine control unit. Some specimens were subjected to the cold compression test at room temperature and constant cross head speed. The specimens were subjected to this test to investigate the anisotropy behavior by measuring the flow stress curve at room temperature, and by measuring two perpendicular diameters on the specimen's cross section.

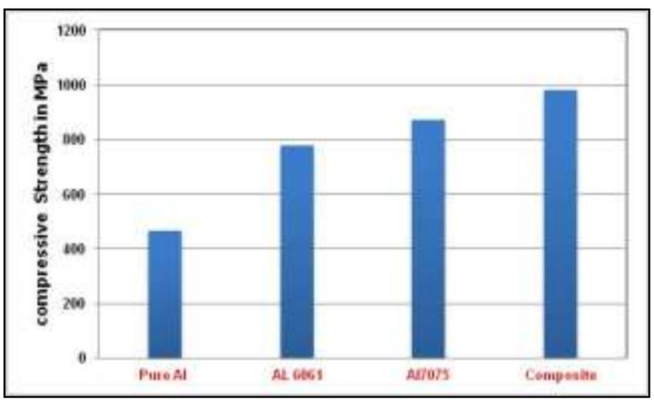


Fig.5. *Compressive strength for different materials*

5. Conclusion

In the present study, we successfully made the Al 7075-Fly Ash with proper distribution of ash particles all over the specimen. We have drawn various conclusions from the various calculations based on the diff. experimental testes: From the study it is concluded that we can use fly ash for the production of composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of fly ash Addition of magnesium and silicon improves the wettability of fly ash with aluminum melt and thus increases the retention of the fly ash in the composite Hardness of commercially aluminum is increased from 95BHN to 138BHN with addition of fly ash and magnesium. The Ultimate tensile strength has improved with increase in fly ash content. Whereas ductility has decreased with increase in fly ash content. The effect of increased reinforcement on the wear behavior of the MMCs is to increase the wear resistance and reduce the coefficient of friction. The MMCs exhibited better wear resistance due to its superior load bearing capacity. The density of the composites decreased with increasing ash content. Hence these light weight composites can be used where weight of an object maters as like in the aero and space industries. From the above results we find the Composite having a good toughness, hardness, tensile strength and also having the low density comparatively alloys. So that these composites could be used in those sectors where light weight and good mechanical properties are required as like in automobile and space industries.

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